RESPIRATORY ONSET DETECTION USING VARIANCE FRACTAL DIMENSION

Yee Leng Yap, Zahra Moussavi
Department of Electrical Engineering
University of Manitoba
Winnipeg, MB R3T 2N2
umyapyl@ee.umanitoba.ca, mousavi@ee.uamanitoba.ca

Abstract ¾ **Recently a non-invasive acoustical method has been developed to detect respiratory phases without airflow measurement, in which the average power of tracheal breath sounds is used to detect the onset of breaths [1]. We improved the accuracy of the breath onsets detection by applying variance fractal dimension D_σ. For the sake of a comparison, the same set of data as in [1] was used. Data included tracheal breath sound recorded simultaneously with airflow from nine healthy subjects. Variance fractal dimension was used to detect the onset of breaths directly from the time domain tracheal sound signals. Result shows that onsets can be detected by the peaks of the variance fractal dimension, with an accuracy of 40±9 ms. Comparing to the accuracy reported in the previous method (41.5±34.7 ms), this study slightly improves the average error but also is more robust in term of standard deviation. It also provides an alternative approach to analyze breath sound signals in time domain. The result increases the reliability of acoustical phase detection algorithm and paves the way for further analysis such as actual amount of airflow estimation.**

Keywords ¾ **respiratory sounds, variance fractal dimension, breath onsets, signal complexity**

I. INTRODUCTION

The determination of respiratory phases is essential in the study of respiratory and swallowing sounds [2]. To date, pneumotachograph, nasal cannulae connected to a pressure transducer, heated thermistor anemometry etc are commonly used to record respiratory airflow [3]. However, each method has its limitations when assessing the airflow of either a neurological impaired patient or a patient with physical deformities. In addition, some may even alter the pattern of respiration [1]. Acoustical analysis of respiratory sounds has recently provided an alternative way to detect respiratory phases without airflow measurement [1]. The acoustical phase detection algorithm has shown promising results in respiratory phase detection by using only tracheal and chest sounds. Breath onsets were detected by detecting minimum points of the average power of tracheal signals, where the tracheal sound intensity was low [1]. In this study however, we aimed to investigate the fractal dimension of the tracheal sound signal as another approach to detect the breath onsets.

Fractal dimension is a measure of complexity in a data set, either two or three-dimensional images or one-dimensional signals. It is used to analyze chaotic and non-chaotic signals in a wide range of scientific research, particularly in image compression, segmentation and in genetic maps [6,7,8]. Fractal dimension quantifies the complexity of an object which is obscure to human eyes. Variance fractal dimension D_σ (Equation 1) is one of the ways to calculate fractal dimension [4,5]. Generally, fractal dimension can be obtained by taking the limit of the quotient of the log change of the object size and the log change of the measurement scale, as the measurement scale approaches zero (Equation 2). In deriving variance fractal dimension for one-dimensional data, sampled signal is the "object", variance (σ) of the sampled signal is the "object size", while the time interval between the samples used to calculate the variance, is the "measurement scale" (Δt_k). One property of fractal dimension is that they are independent of power content in the signal. This indicates that all signals, both with high or low amplitude, will produce the same magnitude of fractal dimension as long as they are composed of the same frequency components. In other words, fractal dimension calculates the complexity of signal and is immune to signal amplitude.

We postulate that breath sound signal has a chaotic feature during the short period of time between the phases (inspiration→expiration or expiration→inspiration). Therefore, we hypothesize that variance fractal dimension of respiratory sound has peaks at the breath onsets and this may lead to a better approach in the automated detection of the breath onsets by acoustical means. Hence, the main objective of this study was to detect and compare the accuracy of breath onset detection using variance fractal dimension with that of the previous method in [1].

II. METHOD

Subjects and data ¾ Data from 9 subjects were adopted from the previous research [1]. The tracheal sound was recorded by accelerometer and airflow was measured by a mouthpiece pneumotachograph. Figure 1 shows a typical sample of the respiratory sound and its corresponded airflow. The airflow and tracheal sound signals were

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25OCT2001	N/A	-

Title and Subtitle Respiratory Onset Detection Using Variance Fractal Dimension	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Department of Electrical Engineering University of Manitoba Winnipeg, MB R3T 2N2	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research Development & Standardization Group (UK) PSC 803 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from the 23rd Annual International conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
3

digitized simultaneously at a sampling rate of 10240 Hz. The detailed information about data can be found in [1].

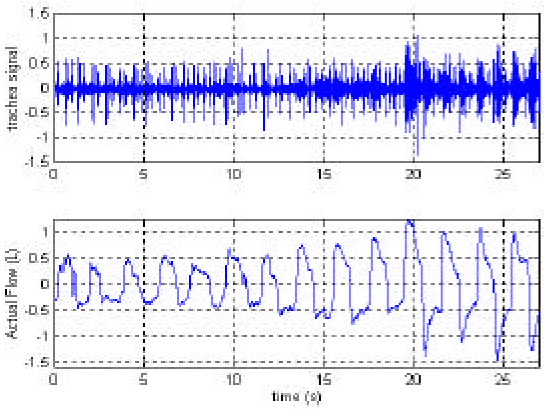

FIGURE 1. A typical tracheal breath sound signal with its associated airflow.

Onset detection by variance dimension ¾ A time series representing a chaotic or non-chaotic process can be analyzed directly by examining the spread of the increments in the signal amplitude, e.g. variance, σ^2.

From [4,5], the variance fractal dimension is defined as:

$$D_\sigma = D_E - 1 + H, \qquad (1)$$

where D_E is the embedding dimension, which is the dimension of the embedding space, (i.e., for a curve D_E=1, a plane D_E=2 and for space D_E=3) and,

$$H = \lim_{\Delta t \to 0} \frac{\log(\mathrm{Var}(\Delta S)_{\Delta t})}{2\log(\Delta t)} \quad . \qquad (2)$$

S is the sound data samples and therefore ΔS is the variation of tracheal sound signal between two points.

$$\Delta t = | t_2 - t_1 |$$
$$(\Delta S)_{\Delta t} = S(t_2) - S(t_1)$$

Figures 2 and 3 show $(\Delta S)_{\Delta t}$ and Δt graphically.

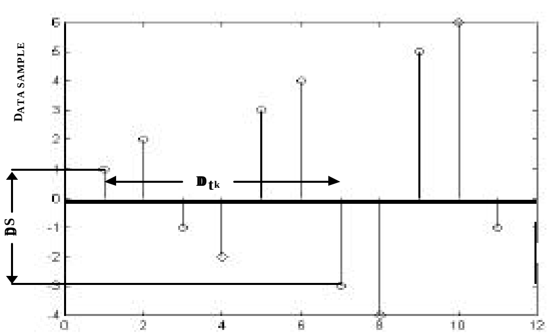

FIGURE 2. Illustrating $(\Delta S)_{\Delta t}$.

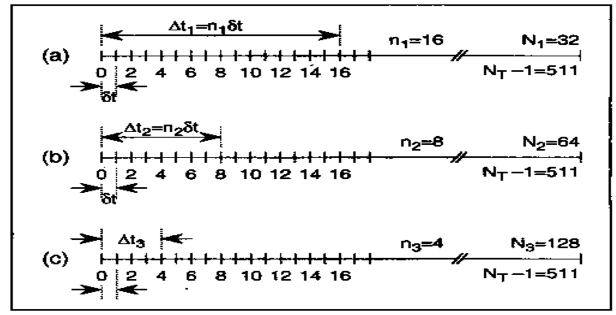

FIGURE 3. Illustrating the measurement scale Δt_K for Dσ calculation. For dyadic measurement scale Δt_K=2, 4, 8, 16, 32,….

To detect breath onsets, D_σ was calculated using N_T=128 points (12.5ms) with 50% overlap between the adjacent segments. Then, a running window with approximately half breath size (0.7second) was used to detect all the peaks in D_σ.

III. Results

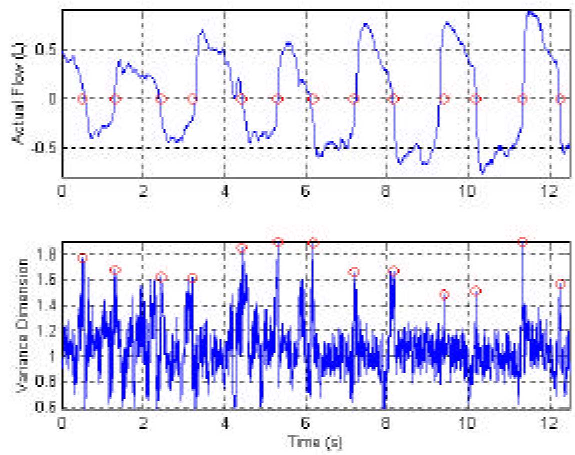

FIGURE 4. An actual airflow signal and the calculated variance fractal dimension. The circles are the detected locations of breath onsets in both plots.

Figure 4 shows the breath onsets detected from variance fractal dimension D_σ with the actual corresponded airflow. Comparing with the actual airflow, the result shows an average error of 40±9 ms, which is slightly less than the error presented in the previous study [1]. However, the standard deviation of the error in this method is much smaller than the previous one.

IV. Discussion

In this study, we postulated that during the transition of breath phases, the sound signal has temporal chaotic features due to the momentum of airflow as it changes its direction. Hence, this leads to a chaotic process, which can be detected by its signal complexity using variance fractal dimension D_σ. As can be seen in Figure 4, variance fractal dimension approaches a value of two, indicating the signal during transition of phases has a complexity between a line and a plane. It cannot be a pure line because all data points do not lie in a straight line; it cannot be a plane as well since the area for one-dimensional signal is zero. This important characteristic of non-integer fractal dimension has been used extensively in describing and classifying speech phonemes [9].

The advantage of variance fractal dimension D_σ is that it does not compromise between frequency and time resolution, while the accuracy of breath onset detection by average power method depends on the window size to segment data and the window size option is limited by the trade off between the time and frequency resolution. D_σ, however, concerns solely with time resolution N_T. By changing the size of N_T, the magnitude of D_σ also changes. Optimum N_T interval size is obtained when D_σ shows prominent peaks.

The attraction of variance fractal dimension is also that D_σ can be calculated directly in time-domain. It can be programmed to have a real-time procedure to calculate D_σ while tracheal sound signal is being received.

In conclusion, the result of breath onset detection using variance fractal dimension is encouraging. Further experiments have to be carried out to examine whether variance fractal dimension is also useful in determination of respiratory phases from the chest sound signals.

ACKNOWLEDGMENT

This project was supported by the Natural Science and Engineering Research Council of Canada (NSERC).

REFERENCES

[1] Z. Moussavi Z. M. T. Leopando, H. Pasterkamp, G. Rempel, "Computerized acoustical respiratory phase detection without airflow measurement", Medical & Biolog Eng. & comp, 38 (2):198:203, March 2000.

[2] Selley W.G, Ellis R.E, Flack F.C, Bayliss C.R and Pearce V.R., 1994. "The synchronization of respiration and swallow sounds with videofluroscopy during swallowing". Dysphagia 9, 162-167

[3] Tarrant S.C, Ellis R.E, Flack F.C, and Selley W.G., 1997. "Comparative review of techniques for recording respiratory events at rest and during deglutition", Dysphagia 12, 24-38.

[4] W. kinsner, "A unified approach to morphological, entropy, spectral, and variance fractal dimension", 10th International Conference on Mathematical and Computer Modeling Record, ICMCM'95 (Bostron, MA; July 5-8, 1995).

[5] W. Kinsner and W. Grieder, "Fractal amplification of signal feature using variance fractal dimension," 10th International Conference on Mathematical and Computer Modeling Record, ICMCM'95 (Boston, MA;July 5-8, 1995)

[6] Caetano Traina Jr., Agma Traina, Leejay Wu and Christos Faloutsos, "Fast feature selection using the fractal dimension", XV Brazilian Symposium on Databases (SBBD), Paraiba, Brazil, October 2000

[7] Christos Faloutsos and Ibrahim Kamel Beyond Uniformity and Independence: Analysis of R-trees Using the Concept of Fractal Dimension Proc. ACM SIGACT-SIGMOD-SIGART PODS, Minneapolis, MN, May 24-26, 1994, pp. 4-13.

[8] Christos Faloutsos and Volker Gaede "Analysis of the Z-Ordering Method Using the Hausdorff Fractal Dimension", Conf. on Very Large Data Bases (VLDB), Bombay, India, Sept. 1996.

[9] S Fekkai, M AI-Akaidi and J M Blackledge, "Fractal Speech Processing" IMA Conference on Fractal Geometry: Mathematical Techniques, Algorithms and Applications, September 20, 2000